SLOPE STABILITY INVESTIGATION
Proposed Ninety Feet High Cut Slope
Puu Pahu Ridge, Lilipuna Road
Kaneohe, Oahu, Hawaii

For

Zeller Associates
Mr. J. Lynwood Zeller

Tax Map Key 4-5-45:33
Project No. 102-01 A
March 3, 1975

Submitted By
H. PATEL, INCORPORATED
677 Ala Moana Blvd, Suite 302
Honolulu, Hawaii 96813

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H. PATEL, INCORPORATED

GEOTECHNICAL ENGINEERING

Mr. J. Lynwood Zeller, General Partner
Zeller Associates
P.O. Box 1273
Kailua, Hawaii 96734

March 3, 1975
Project No. 102-01 A

Dear Mr. Zeller,

Submitted herewith are three copies of our report entitled "Slope Stability Investigation, Proposed Ninety Feet High Cut Slope, Puu Pahu Ridge, Lilipuna Road, Kaneohe, Oahu, Hawaii" for Zeller Associates. TMK for the project is 4-5-45:33. This investigation was performed in accordance with our authorized proposal dated Feb 3, 1975, and the general conditions attached with the same. During the course of our investigation, we have discussed the project with Mr. Zeller and Mr. Watson Lee.

It is our opinion that the site is suitable, from Soil Engineering viewpoint, for a cut slope provided that the recommendations of this report and applicable grading codes are followed. Due to highly decomposed and weathered condition of basalt in west area of the site, we recommend flatter slope in the western portion of the proposed cut slope. Erosion protection measures should be immediately implemented after grading the cut slope.

This report is based on presently available information only. If any conditions are encountered that are not covered in this report or are contrary to the contents of this report, the Soil Engineer should be immediately consulted to review the conditions and, if neccessary, to issue revised recommendations. The grading work should be performed under the inspection of a Soil Engineer.

It has been our pleasure to conduct this investigation for you. If you have any questions please do not hesitate to contact us.

Yours Very Truly

H. PATEL, INCORPORATED

H. M. PATEL
REGISTERED PROFESSIONAL ENGINEER
No. 3352
HAWAII, U.S.A.

Hemant M. Patel, President

HMP/bk
Three copies submitted

C.C. Watson Lee, Incorporated Attn: Mr. Watson Lee (1)

SLOPE STABILITY INVESTIGATION
Proposed Ninety Feet High Cut Slope
Puu Pahu Ridge, Lilipuna Road
Kaneohe, Oahu, Hawaii
For
Zeller Associates

INTRODUCTION

This report presents the results of our preliminary soil investigation for the above referenced project. The investigation consisted of subsurface borings, laboratory testing and engineering analyses as outlined in our authorized proposal dated Feb. 3, 1975. Basically, the scope of our investigation was to evaluate the nature of the subsurface conditions and develop slope stability recommendations for use during the design stage of the project.

PROPOSED DEVELOPMENT

The site to be developed is located behind 45-731 Lilipuna Road in Kaneohe and comprises of south western portion of Puu Pahu Ridge. The Puu Pahu Triangulation Station is located near the northeast corner of the property. The Tax Map Key of the site is 4-5-45:33 and the area is approximately four acres. Parcle 60 is excluded from the scope of this report. The general site location is shown on Plate 1-A.

During the course of our investigation, we have referred to :

(1) Grading Plan, dated October 17, 1974, prepared by Watson Lee, Incorporated, Civil Engineering Consultants
(2) Contour Map, dated Feb. 17, 1973, prepared by Park Engineering, Incorporated
(3) Driller's Daily Boring Logs for four borings drilled by Continental Drilling Company in December 1973
(4) Laboratory Test Results and a letter, not dated, from Ahsing and Associates
(5) Letter from Watson Lee, Incorporated, dated November 6, 1974 regarding the need for a report by a Registered Soil (Civil) Engineer.

Based on the above references and discussions with Mr. Zeller, we understand that it is proposed to develop the site for about seven building Lots. It is anticipated that considerable grading, mainly excavation, would be required to achieve the pad elevation required by the Water Department for delivery of water at the site. Topographic relief on parcle 33 is estimated to be on the order of 120 feet. It is proposed to create a Cut Slope of about 90 feet height on the site for which a Slope Stability Investigation, as presented by this report, is neccessary. The cut slope is planned for 1:1 gradient.

SUBSURFACE EXPLORATION

The present subsurface exploration consisted of drilling three borings, ranging in depth from 20' 4" to 57' 0", at the locations indicated on Boring Location Plan (Plate 1-B). The boring locations were greatly influenced by existing topography and vegetation at the site and a bulldozer was used to provide access road to borings B and C. The drilling was performed by Continental Drilling Company under our technical directions. A truck mounted Mobil (B-61) drill rig was used. A six inch diameter, continuous flight solid stem auger was used to drill the borings. Standard Penetration 2.0" O.D. split spoon sample and 2.43" I.D. ring samples (3.0" O.D. of ring sampler) were obtained by driving the sampler using a 140 lbs hammer, free falling a distance of 30 inches. The number of blows per foot, reported on the boring logs for the 3.0" O.D. ring sampler, were obtained by dividing the actual number of blows per foot by 2.25 in order to roughly compare them with the standard penetration blow counts which aid in evaluating strength properties of soil. The samples of the subsurface materials were visually identified by us in the field. Representative materials were placed in air-tight bags and returned to our laboratory for further inspection and testing. Log of borings are presented as Plates 2-A to 2-C.

LABORATORY TESTING

Selected samples of the subsurface materials were subjected to various laboratory tests to evaluate their engineering properties. Brief purpose of various tests conducted are presented hereunder.

(1) Moisture Content and Dry Density Tests :- These tests aid in soil classification and evaluating strength and unit weight properties of soil. The results are presented on log of borings (Plates 2-A to 2-C) at the corresponding sample depths.

(2) Sieve Analyses and Plasticity Index :- These tests were conducted for developing engineering classification of soils tested. The results are presented on Gradation Curves (Plates 3-A to 3-C)

(3) Direct Shear Tests :- These tests were performed to evaluate shear strength characteristics of soils tested. The results are presented on Direct Shear Test data in Plates 4-A to 4-B .

ENGINEERING ANALYSES

Engineering analyses primarily consisted of slope stability analyses based on the results of the field exploration and laboratory testing. Shear strength based on tests conducted at natural moisture contents were used for overall slope stability. This was based on the assumption that proper drainage provisions will be designed , constructed and maintained. However, the chances of portions of slope getting saturated can not be over ruled and

hence reduced shear strength parameters were used for analysing a 30 feet high portion of slope. Taylor's stability number charts and NAVFAC, Design Manual 7, Stability Analysis for slopes with ϕ and C were used for the analyses. A minimum Factor of Safty equal to 1.5 was used for the analyses.

SITE CONDITIONS

Surface Conditions :- The site is presently vacant. It is mostly overgrown with a variety of vegetation. Portions of the site are heavily vegetated with lilikoi, guava, plum and other trees and bushes. Some of the areas are bare of vegetation. Piles of trash and other debries are scattered near the lower portion of site. An access road was cleared in the lower portions in past which was partly eroded and partly covered with vegetation at the time of our investigation. This access road and other approach road was cleared to provide access to borings B and C.

Subsurface Conditions :- According to Macdonald and Abbott (Volcanoes in the Sea, 1970, map on page 354) the Puu Pahu Ridge consists of weathered basalt of the Koolau Volcanic Series Dike Complex. The site is basically underlain by following main soil types. Please refer to Plate 1-C.

(1) There is some relatively unconsolidated, weathered, transported soil, filling some lower areas, which has been washed downhill from the higher portions of the site.

(2) Mottled Reddish residual soil covers the southern and western areas of the site. Residual soil overlies Brown to Yellow-Gray highly decomposed basalt from which it was derived. Decomposed to weathered basalt is also exposed in the north eastern areas of the site.

(3) The Koolau Volcanic Series Dike Structure is exposed in the highly decomposed basalt in the southern areas of the site.

(4) The highly decomposed basalt grades into relatively less weathered gray to brown hard Koolau Volcanic Series basalt. A cut for a house on the immediate east of the Puu Pahu Ridge has exposed relatively less weathered basalt. The weathering profile is relatively deeper and soil is relatively softer on the west area of the proposed cut slope than on the east side as indicated by borings and laboratory testing.

RECOMMENDATIONS

General :-

Based upon the results of our field investigation, laboratory testing and slope stability analyses, it is our opinion that the site is suitable for developing the cut slope provided the recommendations of this report and applicable grading codes are followed. The recommendations are based on presently available information only. If any conditions are encountered that are not covered in this report or are contrary to the contents of this report, the Soil Engineer should be immediately consulted to review the conditions and, if neccessary, to issue revised or new recommendations.

Cut Slope :- The results of our slope stability analyses are tabulated below.

Gradient Horz:Vert	Height Feet	ϕ Degrees	C PSF	Safty Factor	Remarks
1:1	90	25	900	1.4	Not acceptable, try 1.5:1 slope
1.5:1	90	25	900	1.6	Acceptable
1:1	90	32	2100	2.3	Acceptable
1:1	90	32	1100	1.6	C reduced, still Acceptable
1:1	30	15	500	1.5	Reduced strength, Acceptable

Based on the results of our investigation it is our opinion that the eastern one third of slope should be grossly stable at planned gradient of (1:1) one horizontal to one vertical. Due to deeper weathering and relatively softer soil in the western area we recommend to use a gradient of (1.5:1) one and one half horizontal to one vertical in the western one third of the cut slope. A gradual transition between 1:1 to 1.5:1 gradients should be provided in the central one third of the cut slope.

Drainage :- The cut slope face should be immediately planted to provide erosion protection. The cut slope designed in accordance with above recommendation should be grossly stable provided that adequate drainage is designed, constructed and maintained on the slope. If any localized sluffing or erosion takes place it should be immediately repaired. The grading code requires 8 feet wide benches at every 15 feet vertical height. We have also considered 4 feet wide benches at every 7.5 feet vertical height. There are three primary purpose of such benches, namely, (1) provide additional stability of slope, (2) intercept sheet flow of water over slope face thus retarding erosion and (3) provide access ways to slope face for maintainance and landscaping. Four feet wide benches at every 7.5 feet height should be acceptable for first two purpose. The width of the benches should be such that they are wide enough to provide access way for maintainance and landscaping. A diverter ditch should be provided on the top of the cut slope to divert water away from the slope face. *

Ground Water : - Ground water was not observed in our borings. If any springs are encountered during construction, subdrains may be required.

Grading :- All deleterious material, i.e., vegetation, top soil, trash etc., should be removed from borrow and fill areas and hauled from the site. All fills placed on grounds steeper than 5 horizontal to one vertical should be properly keyed and benched into firm ground.

Prior to placement of compacted fill in the flatter, lower lying portions of the site, it will also be neccessary to remove all unsatisfactory and soft materials. It is anticipated that these materials will mainly consist of the

old fills placed to create the existing building pads, recent alluvium in the small stream channels, surficial topsoils and existing trash piles. Any excavated natural materials should be approved by the Soil Engineer prior to recompaction as structural fill. Materials of high organic content should not be used. Local soft spots encountered any where on the site, in areas to receive fill, should be removed and replaced with compacted structural fill.

It is expected that majority of weathered rocks should be rippable with conventional rippers. In the event of minor (less than 15 feet height) fill slopes, compaction should be performed progressively, after each three feet increment of fill has been placed, by back rolling with the compaction equipment, or should be over built and subsequently cut back to the compacted core. Two horizontal to one vertical gradient may be used for fill slopes up to 15 feet height and a Soil Engineer should be consulted if higher fill slopes are planned. All fills should be placed in layers not exceeding nine inches, moisture content adjusted to near optimum and be compacted to 90% of maximum dry density obtained by ASTM D:1557-70 test method. All fill materials should be approved by the Soil Engineer.

Retaining Walls :- Free standing, unsurcharged retaining walls less than 10 feet height should be designed for an equivalent fluid pressure of 35 pcf. If a high degree of back fill compaction is required or the walls can not yield even slightly, an equivalent fluid pressure of 60 pcf should be used. Surcharges due to sloping back fill, adjacent footing, hydrostatic pressure, construction equipment etc. must be added to the above values.

Building Set Back :- The buildings should be set back by a minimum distance of 15 feet from the toe and top of the cut slope.

Building Foundation :- After the building locations and type of construction are determined and more definitive development plans are available, the Soil Engineer should be consulted to provide a design level foundation investigation report for presenting recommendations for bearing capacity, foundation type, slab on grade requirements, pavement design parameters, settlements, expansive soil requirements etc.

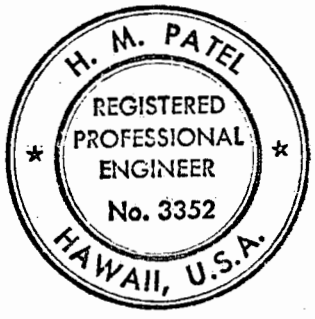
Review and Inspection :- We recommend that grading and foundation plans and related portions of specifications should be reviewed by the Soil Engineer, prior to finalizing them, to verify that the intents of our recommendations are incorporated in the design. The grading operation should be continuously inspected and tested by the Soil Engineer.

The materials encountered in the cut slope should be inspected by the Soil Engineer and/or Engineering Geologist to verify that the recommended gradient would be grossly stable. If hard, relatively unweathered massive basalt is encountered in the cut slope, the gradient may be steepened upon recommendation of the Soil Engineer and/or Engineering Geologist.

We appreciate this opportunity of serving you. If there are any questions, please do not hesitate to call this office.

The following plates are attached with and complete this report :-

Plate 1-A	General Site Location
Plate 1-B	Boring Location Plan
Plate 1-C	Generalized Subsurface Conditions
Plates 2-A to 2-C	Boring Logs
Plates 3-A to 3- C	Gradation Curves
Plates 4-A to 4-B	Direct Shear Test Data



Respectfully Submitted,
H. PATEL, INCORPORATED

Hemant M. Patel, P. E.

Checked by [signature] Date 3-3-75

GENERAL SITE LOCATION

Project TMK 4-5-45:33 Slope Stability Investigation

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Date 3-3-75

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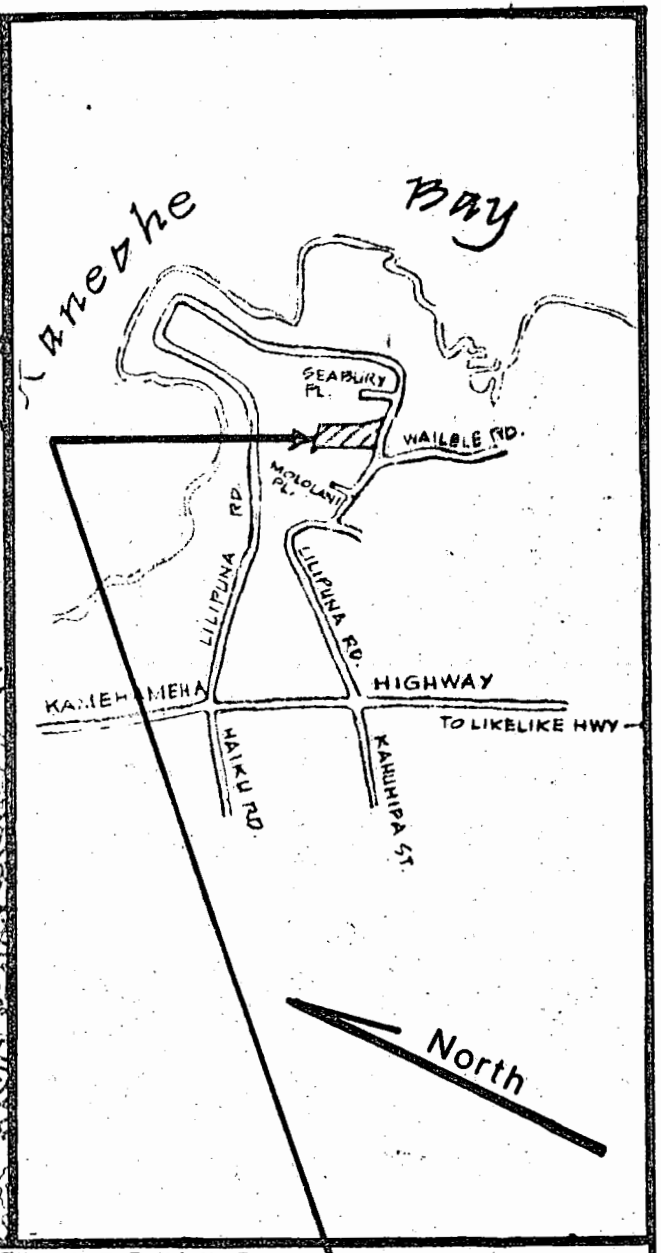
GEOTECHNICAL ENGINEERING

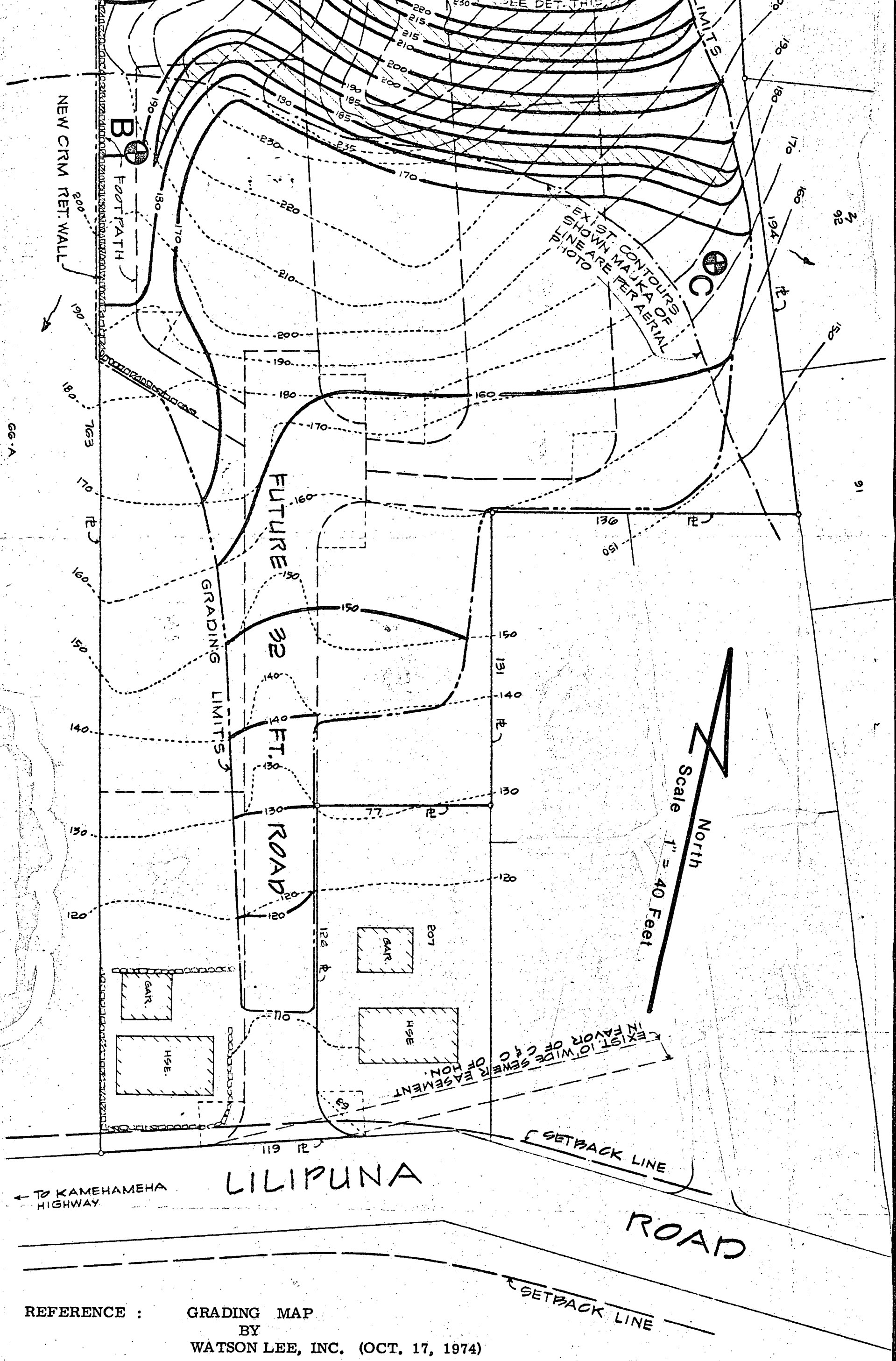
Plate 1-A

GENERAL SITE LOCATION

REFERENCE : TOPOGRAPHIC MAP OF THE ISLAND OF OAHU
U. S. GEOLOGICAL SURVEY REVISED 1970
SCALE 1 : 62500



REFERENCE : GRADING MAP
BY
WATSON LEE, INC. (Oct 17, 74)



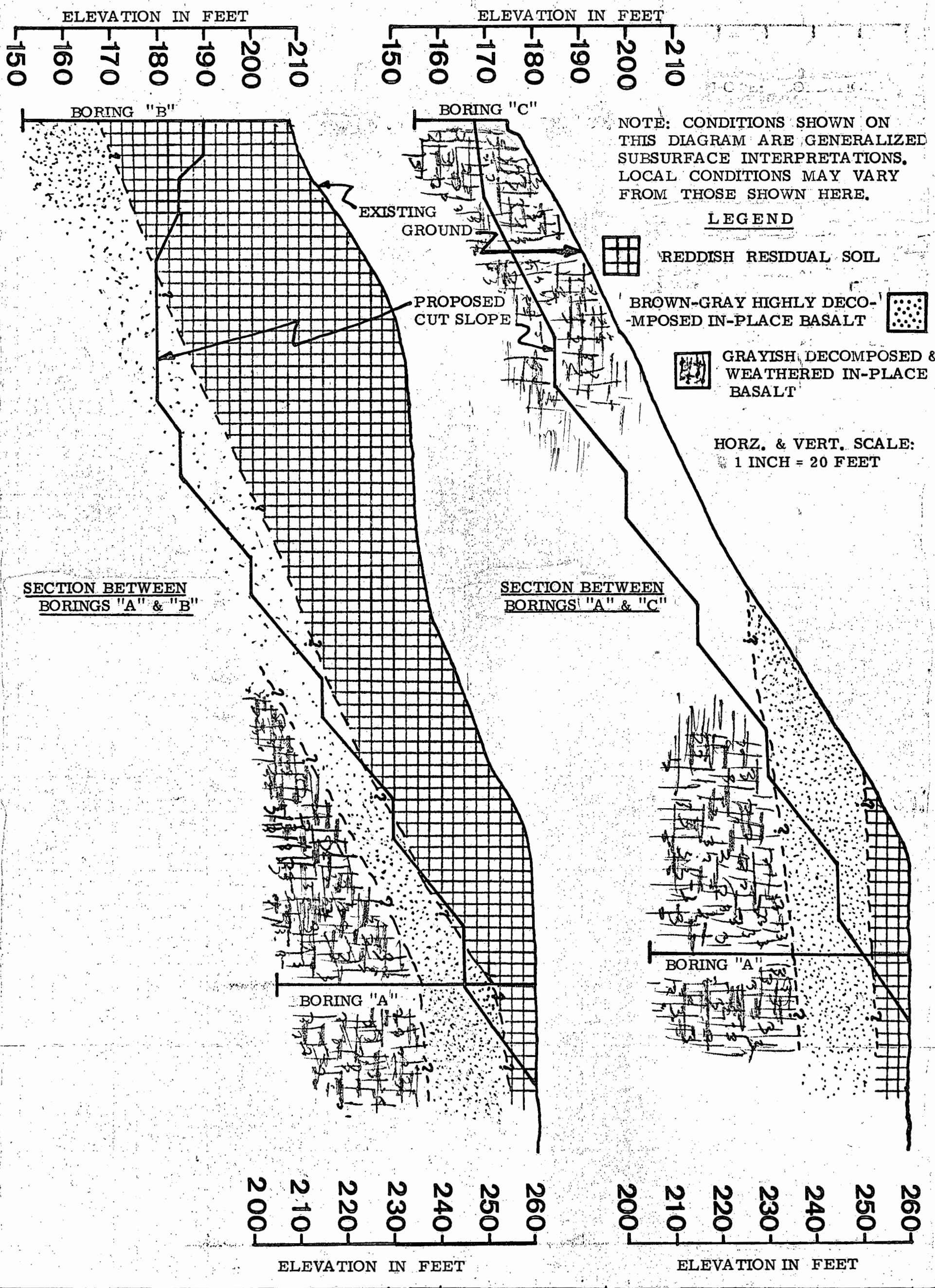
REFERENCE : GRADING MAP
BY
WATSON LEE, INC. (OCT. 17, 1974)

C⊕ BORING DESIGNATION AND LOCATION

BORING LOCATION PLAN

Project TMK 4-5-45:33 Slope Stability Investigation	H. PATEL, INCORPORATED GEOTECHNICAL ENGINEERING	Plate 1-B
Project No. 102-01A		
Date March 3, 1975		

Checked By [signature] Date 3-3-75



GENERALIZED SUBSURFACE CONDITIONS

Project TMK 4-5-45:33 Slope Stability Investigation	H. PATEL, INCORPORATED GEOTECHNICAL ENGINEERING	Plate 1-C
Project No. 102-01A		
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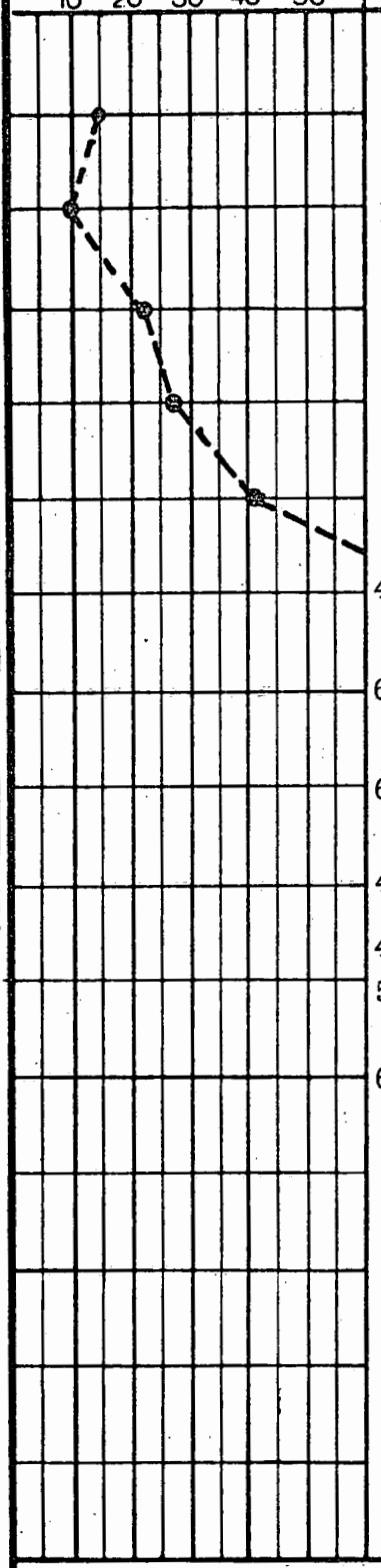

Blows/Foot	% Moisture Content	Dry Density PCF	Samples	Depth in Feet	U S C	Description
	42.9		⊠		MH CH	SILT, Clayey, Mottled Red, Moist Stiff, Plastic (Residual Soil)
15	36.8	75.7	□	5		
10	32.8	66.2	□	10	MH	SILT, Mottled Brownish-gray with yellow and black stains, Moist, Stiff, Almost non-plastic, Few fine decomposed roots. Grades Stiffer and less Moisture (Highly decomposed in-place basalt)
22	23.6	86.3	□	15		
27	24.4	84.6	□	20		
41	20.5	94.4	□	25	SC	SAND, Fine with trace of medium to coarse sand, Mottled Gray-Brown with Brown & Black Streaks, Very Compact, With some Clay (Decomposed Basalt)
47/6"	12.7	103.2	▬	30		
62/6"	15.7	114.5	▬	35		Grading less decomposed with occasional pieces of in-place weathered basalt.
67/6"	10.7		▬	40		
45/3"			▬	45		
46/6"	8.7	110.8	▬			
56/3"	8.4		▬	50		
67/6"	6.4		▬	55		Boring Completed @ 55'6", Feb 10, 75
				60		Ground water not encountered.

Surface Elevation Approx. 260 Ft.
Type of Boring 6" ϕ Solid Stem Auger
B-61, Truck Mounted Rig

Checked by _____ Date 3-3-75

Notes: ⊠ Bulk Sample
■ 2.0" O.D. split-spoon sample
□ 2.5" O.D. ring sample
I Core sample
✱ Sample not recovered
▽ Observed water level
USC - Unifed Soil Classification

LOG OF BORING No. A

Project TMK 4-5-45:33 Slope Stability Investigation
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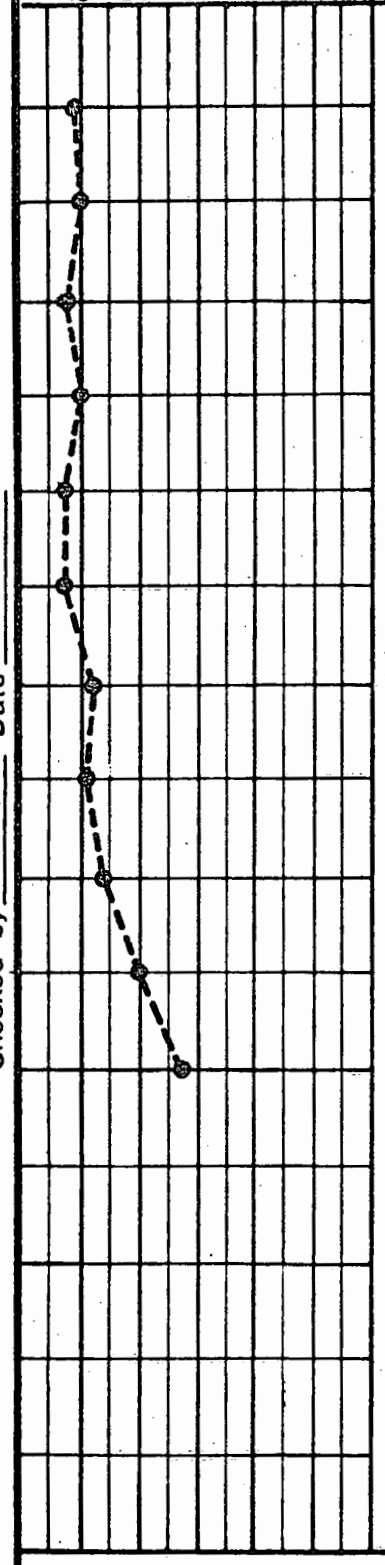
Plate 2-A



Blows/Foot	% Moisture Content	Dry Density PCF	Samples	Depth in Feet	USC	Description
					MH	SILT, Clayey, Mottled Red, Very Moist, Stiff, Plastic, Yellow spots & Black Streaks. (Residual Soil)
9	57.8	61.4	□	5		
10	54.7	63.8	□	10		
8	53.8	64.4	□	15		
10	45.8	70.6	□	20		
7	55.5	60.9	□	25		Grading Medium Stiff
7	53.2	65.3	□	30		Grading Stiff and color changed to Mottled Brownish-Grayish with yellow spots and red & black streaks, Trace of fine sand.
12	55.0	63.8	□	35		
11	56.3	63.5	□	40		
					MH	SILT, Trace of Clay and Fine Sand, Mottled Gray with red, brown & black streaks, Almost non-plastic, Moist, Very Stiff. Pieces of highly weathered Basalt which can be crushed with finger pressure. (Highly decomposed in-place basalt)
14	47.4	72.3	□	45		
20	46.1	68.2	□	50		
27	39.1	75.7	□	55		
				60		Boring Completed @ 57'0", Feb 12, 75
						Ground water not encountered

Surface Elevation Approx. 208 Ft.
Type of Boring 6" ϕ Solid Stem Auger
B-61, Truck Mounted Rig

Checked by Date 3-3-75

Notes:
- ■ 2.0" O.D. split-spoon sample
- □ 2.5" O.D. ring sample
- I Core sample
- ✱ Sample not recovered
- ▽ Observed water level

USC - Unifed Soil Classification

LOG OF BORING No. B

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Plate 2-B

(Ring Sampler blows are divided by 2.25)
Blows/Ft. on Sampler
140 lb. hammer - 30 in. drop
10 20 30 40 50

Surface Elevation Approx. 175 Ft.
Type of Boring 6' ϕ Solid Stem Auger
B-61, Truck Mounted Rig

Blows / Foot	% Moisture Content	Dry Density PCF	Samples	Depth in Feet	USC	Description
				1	SM	Weathered basalt boulders and SAND, Silty, with Fine angular gravel, Brownish gray, Slightly moist, Very Compact. (Highly weathered in-place basalt)
43/6"	13.5			5		
44/3"	6.8			10		
44/2"	5.3			15		
44/3"			*	20		Boring Completed @ 20'4", Feb 18, 75
100/1"			*			
				25		Ground water not encountered.

Checked by [signature] Date 3-3-75

Notes:
- ▩ 2.0" O.D. split-spoon sample
- □ 2.5" O.D. ring sample
- I Core sample
- * Sample not recovered
- ▽ Observed water level
- USC - Unifed Soil Classification

LOG OF BORING No. C

Project TMK 4-5-45:33 Slope Stability Investigation
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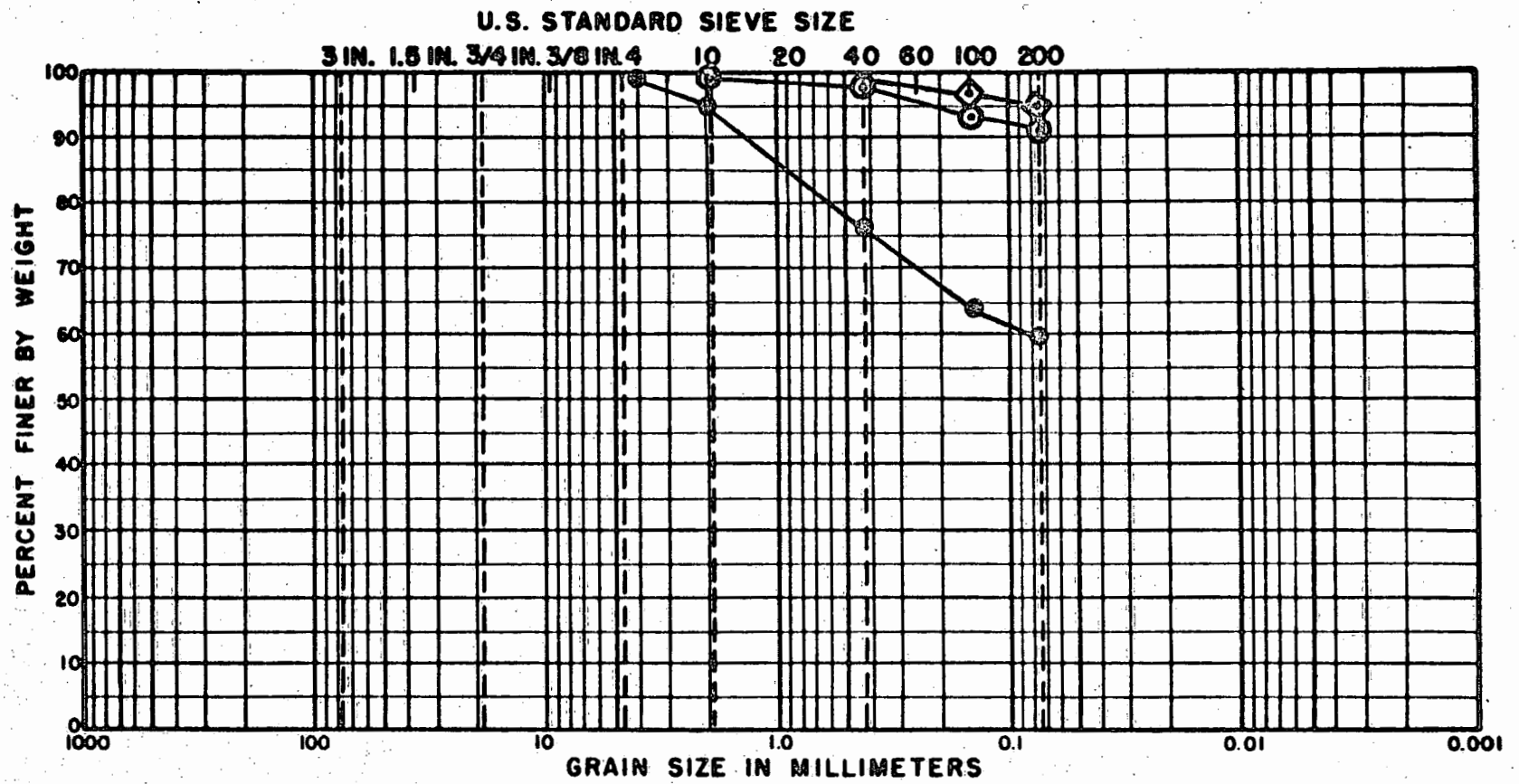
Plate 2-C

Checked by Amrat Date 3-3-75



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

BORING	DEPTH	CLASSIFICATION	NAT. MC	LL	PL	PI
◎ A	5'0" to 5'6"	MH-CH Silt, Clayey	36.8	71	43	38
◇ A	20'0" to 21'6"	MH Silt	24.4	59	40	19
● A	30'0" to 30'6"	SC Clay and Sand	12.7	35	8	27

GRADATION CURVE

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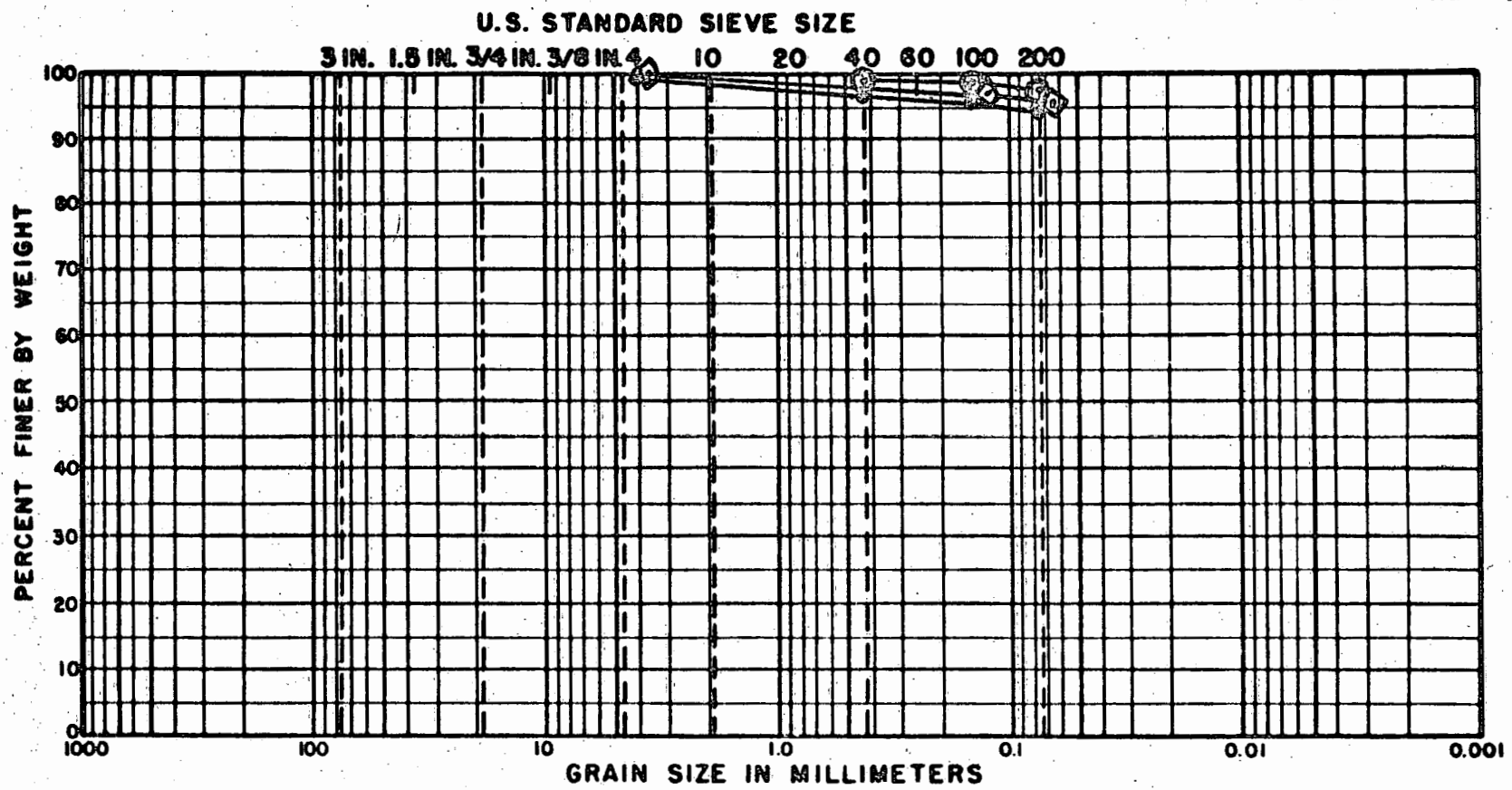
Plate 3-A

Checked by AMK Date 3-3-75



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

BORING	DEPTH	CLASSIFICATION	NAT. MC	LL	PL	PI
⊙ B	5'0" to 5'6"	MH Silt	57.8	78	58	20
◇ B	35'0" to 36'6"	MH Silt	55.0	69	49	20
● B	45'0" to 45'6"	MH Silt	47.4	68	44	24

GRADATION CURVE

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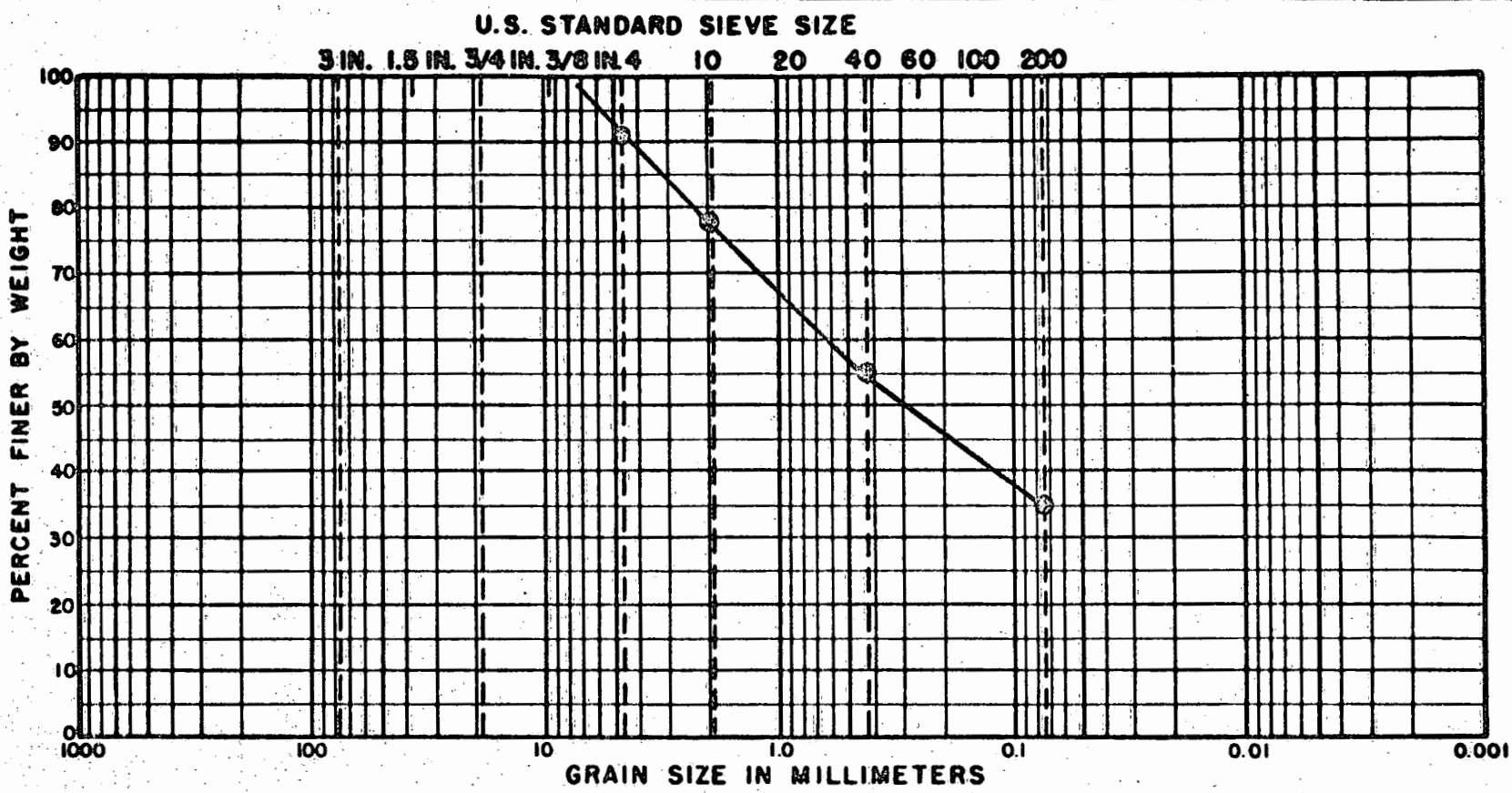
Plate 3-B

Checked by Amd Date 3-3-75



BORING	DEPTH	CLASSIFICATION		NAT. MC	LL	PL	PI	
● C	5, 10 and 15 Feet	SM	Sand, Silty with Fine Gravel	Avg. 8.5	Non-Plastic			Mixture of 3 samples

GRADATION CURVE

Project: TMK 4-5-45:33 Slope Stability Investigation

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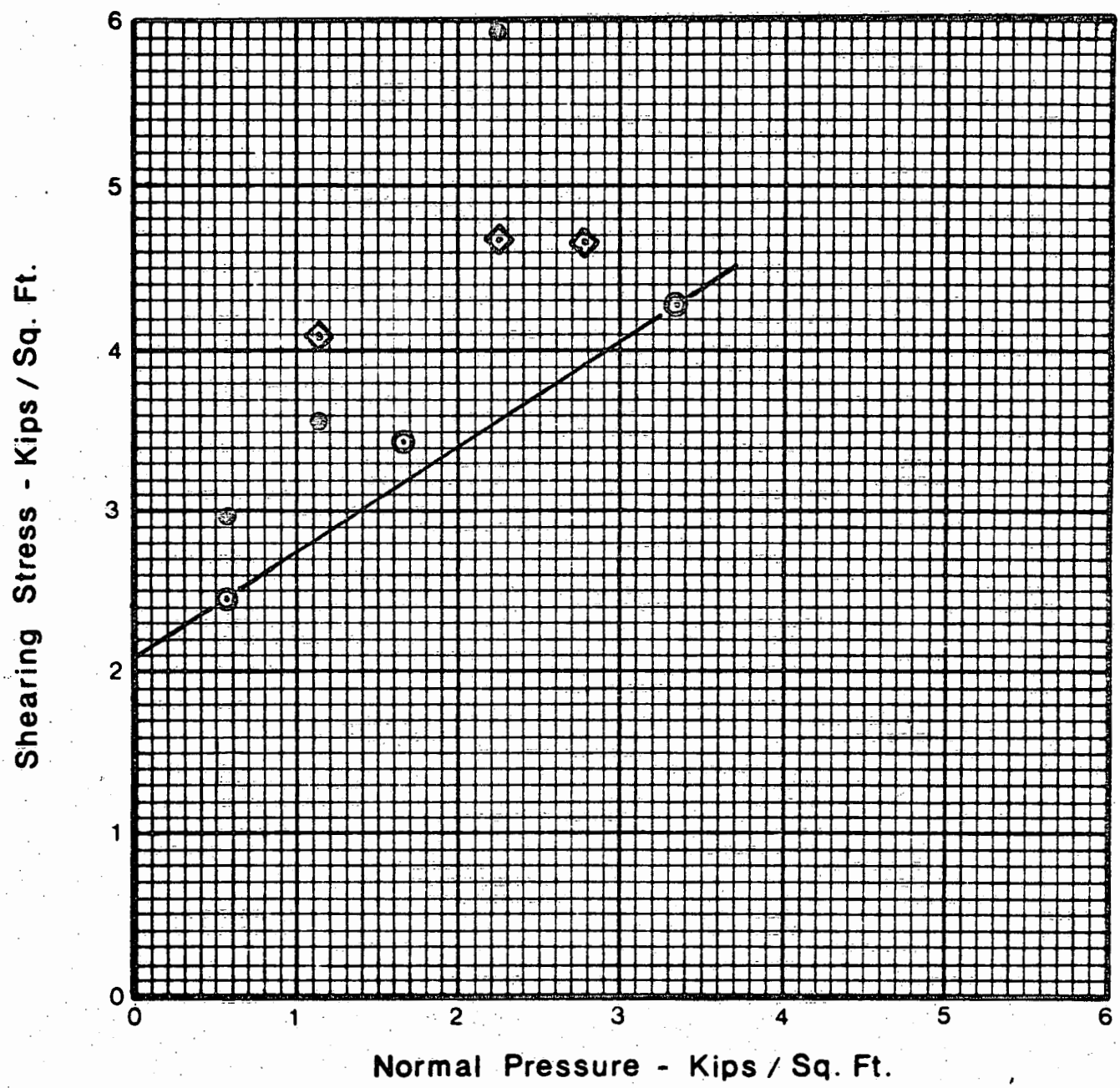
Plate 3-C

Checked by _____ Date 3-3-75



BORING:	SAMPLE DEPTH:
◎ A	5' 0" to 6' 6"
◇ A	20' 0" to 21' 6"
● A	30' 0" to 30' 6"

DESIGN SHEAR STRENGTH PARAMETERS $\phi = 32^{\circ}$ & C = 2100 PSF

DIRECT SHEAR TEST DATA

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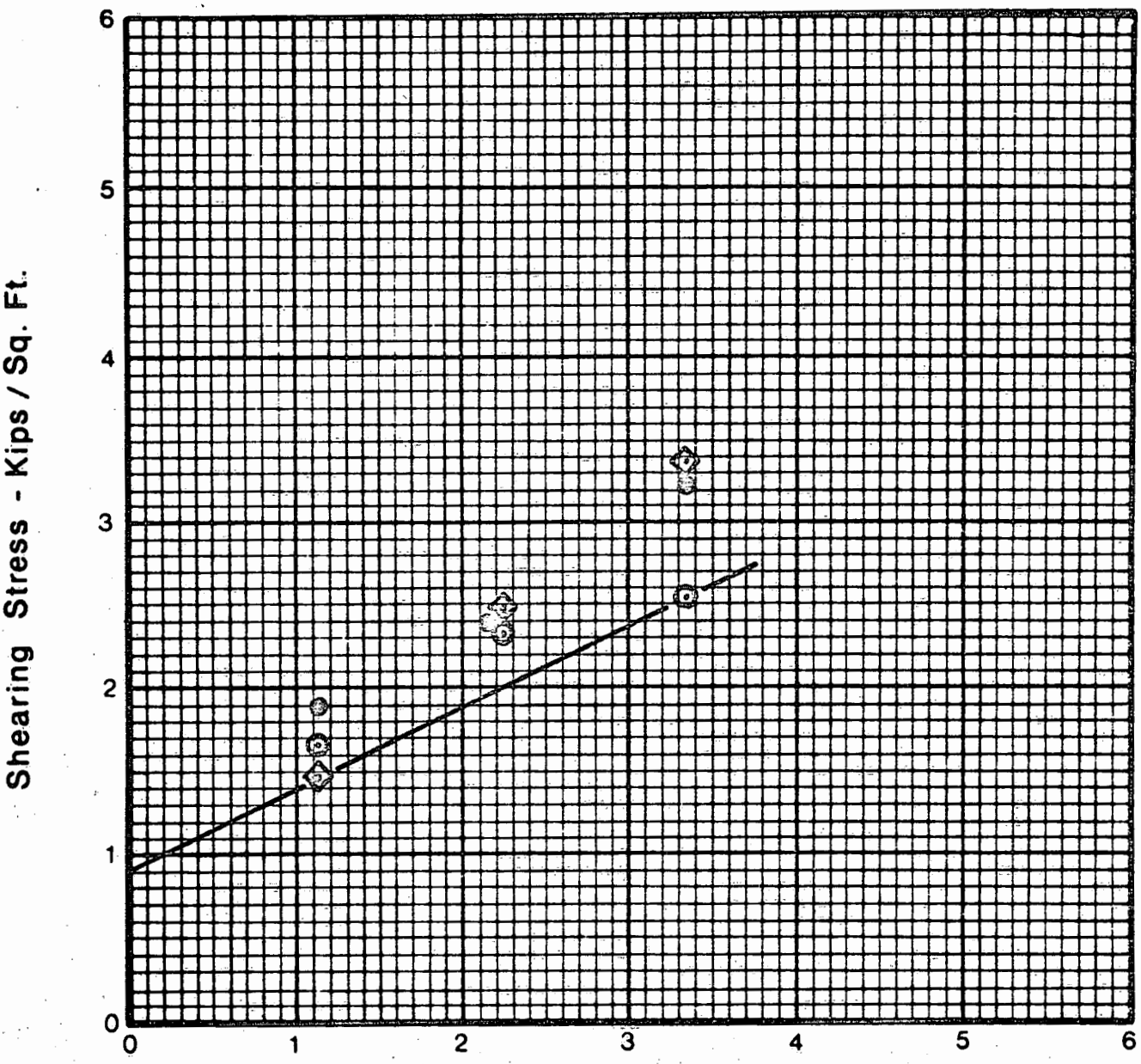
Plate 4-A

Checked by [signature] Date 3-3-75



BORING:	SAMPLE DEPTH:
◎ B	5' 0" to 6' 6"
◈ B	35' 0" to 36' 6"
● B	45' 0" to 46' 6"

DESIGN SHEAR STRENGTH PARAMETERS $\phi = 25^{o}$ & C = 900 PSF

DIRECT SHEAR TEST DATA

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Plate 4-B